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THE INFLUENCE OF PHYSICAL PROPERTIES ON THE COMPRESSIVE STRENGTH OF THE ROCK IN THE SAMIGALUH AREA, KULON PROGO, INDONESIA

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ABSTRACT

The Samigaluh area, Kulon Progo, Indonesia, is composed of rocks from the Old Andesite and Jonggrangan Formations, with very different physical properties. The difference in physical properties indeed results in the engineering properties of rocks, for example, in terms of compressive strength. Studying the relationship between physical properties and rock compressive strength in these two different formations is exciting to find out the extent of the relationship between physical properties and rock engineering. A geological engineering survey was carried out simultaneously with the collection of six rock samples representing intrusive andesite, andesite (breccia and lava fragments), and tuff of the Old Andesite Formation (OAF), limestone (reef/calcarenite) Jonggrangan Formation. Furthermore, rock samples were analyzed physically (petrographically) and mechanically (compressive strength) in the laboratory.

The results of field surveys and analysis of laboratory data yield knowledge about the relationship between the physical properties of rocks and their compressive strength. The intrusion andesites and OAF andesites generally have a porphyroaphanitic texture, anhedral - subhedral, hypocrystalline, inequigranular crystal form, with a massive structure, and the composition of plagioclase, quartz, and accessory minerals (hornblende). Fine-textured tuff, hypocrystalline, in the form of glass and crystal tuffs. The Jonggrangan limestones are fine to medium textured, well-sorted, grain supported, with variations of wackestone – packstone. The compressive strength of andesite is 39.98 – 49.36 MPa, calcarenite is 43.32 MPa, reef limestone is 20.44 MPa, and tuff is 11.15 MPa. The compressive strength of rock is influenced by texture (grain size/crystal) with a correlation coefficient of 68% (strong correlation). In comparison, rock composition (percentage of quartz) has a very weak correlation (correlation coefficient of 18%).

KEYWORDS: correlation, physical properties, compressive strength, andesite, limestone.

INTRODUCTION

The Kulon Progo hills are composed of various kinds of rocks, both sedimentary and igneous rocks. These rocks can be grouped into the Nanggulan, Old Andesite, Jonggrangan, Sentolo Formations, Alluvial Deposits, and intrusion rocks (Van Bemmelen, 1949; Rahardjo et al, 1977).

The Old Andesite Formation and Jonggrangan Formation are composed of very different rocks, whereas relatively hard and coarse volcanic rocks dominate the Old Andesite Formation. In contrast, the Jonggrangan Formation is mainly composed of layers of carbonate/carbonate sedimentary rock, relatively fine and soft-grained. With these contrasting petrophysical differences, of course, the engineering properties of rocks will also be different.

Brotodiharjo (1979) stated that mineral hardness would determine the compressive strength of rocks. The hardness of this mineral depends on its mineral composition. Therefore, the compressive strength will be determined by the rock type. In addition, some physical properties of rocks that can affect the value of compressive strength are rock texture, porosity, the presence of fractures/cracks, and weathering conditions of rock.

Physical properties of rocks affect the hydraulic characteristics (Listyani, 2020); besides, physical properties also affect the engineering properties of rocks (Brotodiharjo, 1979). Thus, rock physical properties are important in determining rock characteristics related to hydrogeological and engineering geology aspects.

This study specifically examines the differences in physical properties and compressive strength of these two formations, which is very interesting to see how much the physical properties of rocks determine the value of compressive strength. The correlation between physical properties that appear in petrological/petrographic characteristics is discussed to determine the relationship between physical and mechanical properties of rocks.

MATERIALS AND METHODS

Geological Settings

The research area is included in the Dome in the Central Depression Zone, according to Van Bemmelen (1949), especially in the Samigaluh District (Figure 1). The study area is composed of rocks from the Old Andesite and Jonggrangan Formation.

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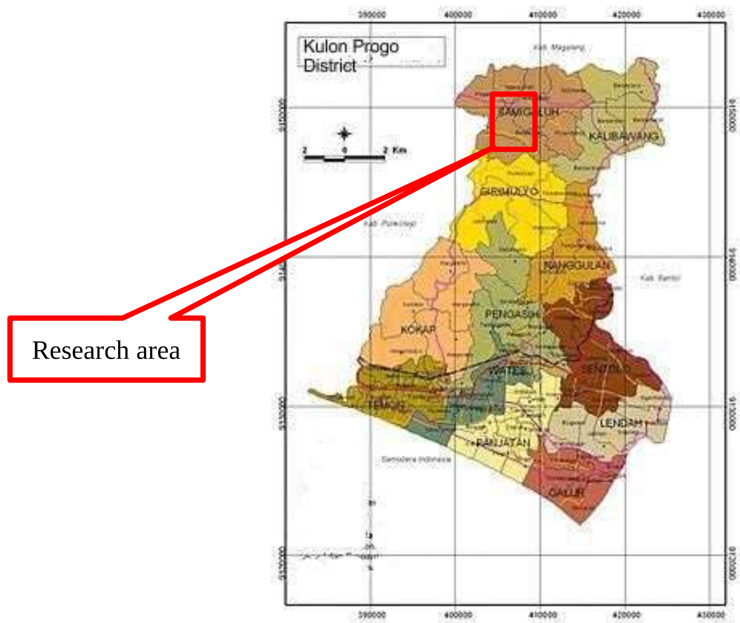

Figure 1. The research area is located in the Samigaluh area, Kulon Progo District, Java, Indonesia.

The Old Andesite Formation is composed of rocks deposited in a volcanic environment, composed of breccia, lava, lapilli, tuff, and sandstone. The dominant constituent lithology consists of andesite breccia with a tuff or tuffaceous sandstone matrix, and fragments consist of pyroxene andesite to hornblende andesite. The Old Andesite Formation results from ancient volcanic activity, namely Mount Gadjah, Ijo, and Menoreh. Meanwhile, the Jonggrangan Formation is composed of tuffaceous marl, calcareous sandstone with lignite insertions that move upwards into layered limestones and coral limestones that form reefs (Rahardjo et al., 1977).

Field Sampling

Six rock samples were selected to represent intrusive andesite rock; OAF andesite lava, breccia fragments and tuff; and Jonggrangan limestones. The location of the side points can be seen in Table 1 and Figure 2. The description of the physical properties of rocks is carried out through direct observations in the field, including color, texture, structure, and composition.

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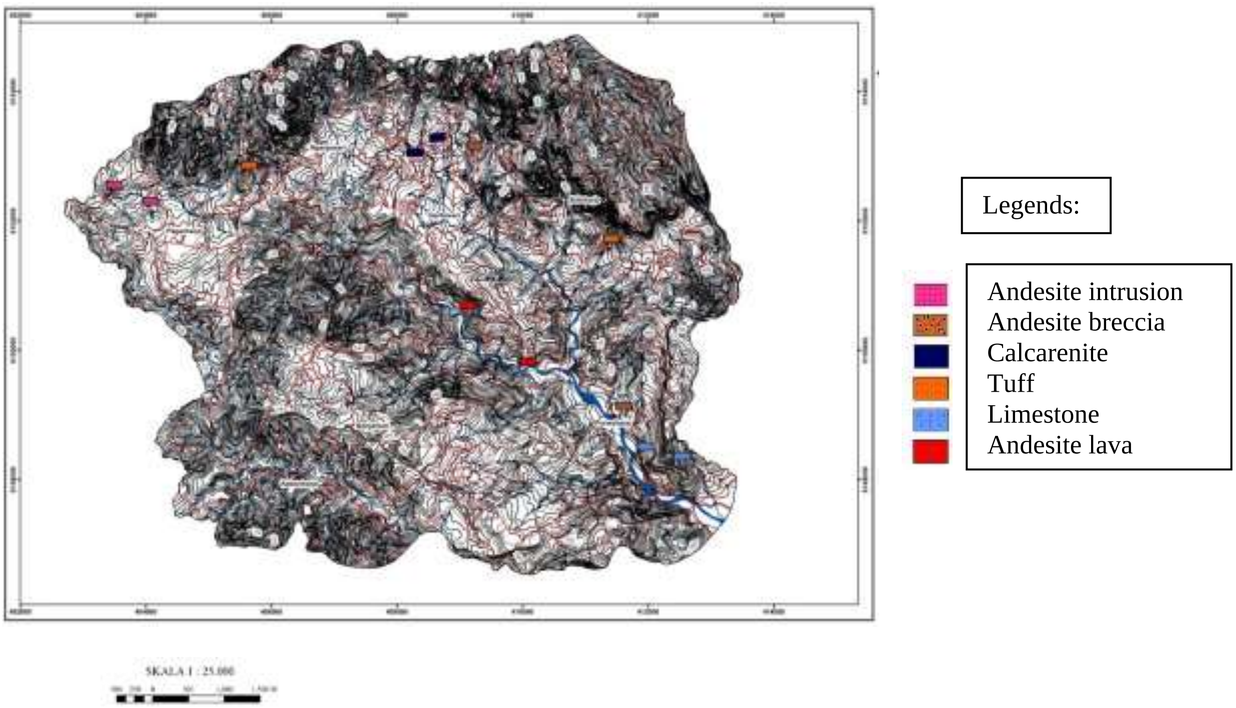

Figure 2. Map of the sampling location.

Table 1. Rock sampling locations.

No	VILLAGE	Coordinate (º)		Code Sample	Rock
		Easting	Northing		
1	Pagerharjo	-7.667568	110.123774	LDA	Andesite intrusion
2	Gerbosari	-7.659616	110.169162	LDG	Jonggrangan calcarenite
3	Sidoharjo	-7.661274	110.176048	LDD	Fragment of OAF andesite breccia
4	Sidoharjo	-7.674923	110,195895	LDC	OAF tuff
5	Purwoharjo	-7.703489	110.187473	LDF	Jonggrangan reef limestone
6	Purwoharjo	-7,692100	110.187473	LDB	OAF Andesite lava

Laboratory Analysis

Rock samples are analyzed to determine physical properties, including a description of the physical properties of rocks and their engineering properties (compressive strength). The description of rock physical properties was carried out megascopically against hand specimens and microscopically.

a. petrographic analysis

Determination of the physical properties of rocks is carried out by petrography, using a polarizing microscope at the Geological Laboratory of the Yogyakarta National Institute of Technology,

b. Rock compressive strength test

The compressive strength test was carried out in the laboratory at the Rock Mechanics Testing Laboratory of PT. Geomine Bara Studio, Yogyakarta. The compressive strength test uses the uniaxial compressive strength (UCS) method based on SNI ISO/IEC 17025:2008 to evaluate rock conditions.

This test is carried out based on a standard that requires sample dimensions under the testing standard, namely, the length of the sample is at least twice the diameter of the sample. It also refers to several researchers such as Karaman et al (2015), Kabilan et al (2016), and Yurdakul et al (2011), who used sample dimensions with a length of more than twice the diameter.

RESULTS

Brotodiharjo (1979) mentions internal factors (physical properties of rock) that affect its compressive strength, including the texture and mineral composition of rocks. Mineral composition greatly influences the resistance indicated by the compressive strength of rocks. Rock texture (grain size) can affect the compressive strength of rocks.

Minerals with a high level of hardness will have high resistance. Sedimentary rocks that contain a lot of quartz minerals as cement will have a higher compressive strength value than sedimentary rocks that do not have a cement composition of quartz minerals. The greater the quartz mineral content, the higher the compressive strength value, while the weakest sedimentary rock is a sedimentary rock with clay mineral composition. Therefore, the study of mineral composition was carried out on the percentage of quartz minerals.

The sample rocks included igneous rocks (andesite breccia intrusions and fragments), sedimentary rocks (limestone), and pyroclastic rocks (tuff). The physical properties of these rocks are different and can be observed in the field, both in fresh and weathered conditions. Megascopically, andesite found in general has a porphyroaphanitic, subhedral, hypocrystalline, inequigranular texture, with a composition of plagioclase, quartz, hornblende, and opaque minerals. The tuff is light, soft, with a fine texture, subhedral, hypocrystalline, and equigranular, and composed of glass and plagioclase. Meanwhile, limestones are generally fine-medium textured, subrounded-rounded grain shape, well sorted and packed tightly, with carbonate and fossil mineral compositions. All rocks are found in fresh until highly weathered conditions, even soil.

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Some examples of the appearance of these rock outcrops can be seen in Figure 3. The petrographic description of these rocks can be seen in Table 2. Furthermore, the compressive strength test results can be seen in Table 3. Moreover, the results of petrography and compressive strength tests were analyzed to see the relationship between physical and mechanical rock properties. The results of the analysis are presented in Figures 4-5.

The physical properties of rocks can mainly be determined by their texture and composition. The textures that can be studied include grain size, shape, and the relationship between grains. However, not all samples showed apparent differences in the texture variables. The grain/crystal shape of the rocks studied generally shows anhedral-subhedral shape, so its correlation with compressive strength is difficult to learn. The relationship between grains is also difficult to check because all igneous rock samples show porphyroaphanitic characteristics, inequigranular; and limestone samples generally show a grain-supported texture. Therefore, the only texture variable that can be studied is the aspect of grain or crystal size. Meanwhile, a study of rock composition was carried out on the number of quartz minerals,

Figure 3. Rock outcrops found in the field: andesite intrusion at Pagerharjo (left); andesite breccia in Sidoharjo (middle); and reef limestones in Purwoharjo (right).

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Table 2. Petrographic description of the rocks studied.

Sample Code	Texture				Composition	Name of Rock
	Grain size (mm)	Shape	Relation			
			Sortation/ Crystallization	Fabric		
LDA	0.2-0.6	Subhedral-anhedral	Porphyroaphanitic, hipocrystalline	Inequigranular	Plagioclase 83%, quartz 7%, hornblende 6%, opaque mineral 4%	Andesite
LDG	0.2-0.6	Rounded-subrounded	Grain supported		Intraclass (20%), ooids (10%), carbonate mud (15%), and skeletal grains (55%)	Packstone
LDD	0.1-0.3	Subhedral-anhedral	Phaneroaphanitic, hypocrystalline	Inequigranular	Plagioclase (albite) 72%, quartz 5%, hornblende 15%, and opaque mineral 8%	Hornblende andesite
LDC	0.1-0.2	Subhedral-anhedral	Hypocrystalline		Plagioclase (albite) 45%, alkali feldspar 25%, quartz 5%, glass 15%, biotite 8%, opaque mineral7%	Crytal tuff
LDF	0.02-0.05	Rounded-subrounded	Grain supported		Pellet (24%), carbonate mud (30%), skeletal grains (46%)	Packstone
LDB	0.1-0.4	Subhedral-anhedral	Porphyroaphanitic, hipocrystalline	Inequigranular	Plagioclase (andesine) 93%, quartz 5%, opaque mineral 2%	Andesite

Table 3. The results of the compressive strength of the rock under study.

Location	Sample Code	Rock	UCS Compressive Strength (MPa)
1	LDA	Andesite intrusion	39.98
2	LDG	Calcarenite	43.32
3	LDD	Fragment of andesite breccia	45.08
4	LDC	Tuff	11.15
5	LDF	Reef limestone	20.44
6	LDB	Andesite lava	49.36

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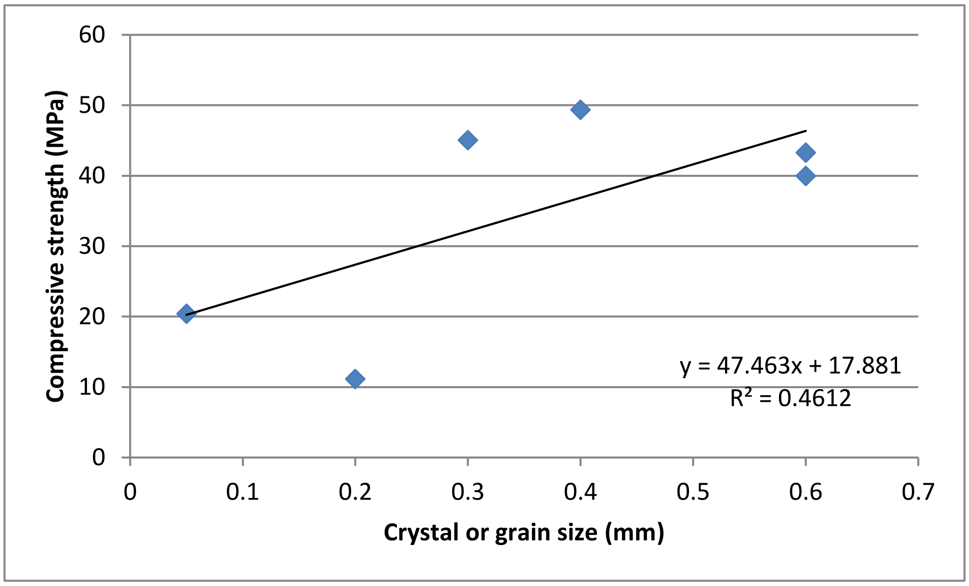

Figure 4. Relation of grain (crystal) size of rock to its compressive strength value.

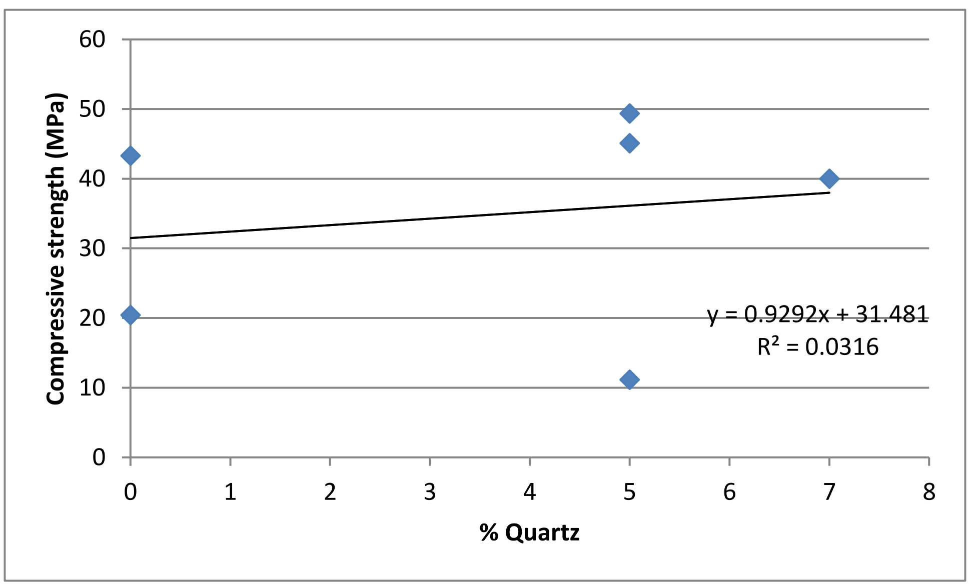

Figure 5. The relationship of the percentage of quartz in the rock to the value of its compressive strength.

The regression test results of the grain size and rock compressive strength variables showed a good relationship, with the R2 value of 0.46, which means it has a correlation coefficient of 68%. This value indicates a strong correlation between the two variables (Sugiyono, 1997; Figure 4).

Meanwhile, the regression results of the relationship between the percentage of quartz and the compressive strength of rocks show a weak correlation. The R2 value for this relationship is only 0.0316, or the correlation coefficient is 18%. This value is a value for a very low level of relationship (Sugiyono, 1997; Figure 5). This shows that the amount of quartz content is not a determinant of the size of the rock's compressive strength.

The regression test results, as presented in Figure 4-5, shows that grain/crystal size plays a more important role in determining the compressive strength of the rock under study. The larger the grain size/crystal, the rock will have a higher compressive strength.

Meanwhile, the results of the correlation of compositions based on the percentage of quartz to the compressive strength of rocks give very low results, indicating that the presence of quartz does not affect the compressive strength of rocks. The calcarenite limestone in LP 2 (LDG sample) shows a high compressive strength value (43.32 MPa). Petrographically, this rock is called packstone, dominated by composition in the form of skeletal grains.

The intact rock sample of the calcarenite limestone shows high compressive strength, one of which is supported by reasonably large grain size. In addition, the process of compaction and lithification certainly greatly affects the physical properties of the rock to increase the hardness of the rock in the study area. Tuff has the lowest compressive strength value; this is supported by conditions in the field which show tuff which is fine-grained, light, and relatively soft.

CONCLUSION

Igneous rocks analyzed in this study are andesite igneous rocks, both in intrusion and OAF lava. The texture of this igneous rock is generally porphyroaphanitic, anhedral - subhedral crystal form, hypocrystalline, inequigranular, with a massive structure, with a dominant composition of plagioclase and accessory minerals in the form of hornblende. The OAF tuff shows a smooth, hypocrystalline, with variations in glass tuff and crystalline tuff. Meanwhile, Jonggrangan limestone shows a fine – medium texture, well-sorted, packed closed, and varies as wackestone – packstone.

The compressive strength values of rock samples in intrusive rocks and the two formations tested varied widely. Andesite rock has a high compressive strength value (39.98 – 49.36 MPa) and calcarenite (43.32

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MPa). Reef limestone has a lower compressive strength, which is 20.44 MPa, while the lowest compressive strength value is shown by a tuff of 11.15 MPa.

The correlation between physical and rock engineering properties in the tested samples is influenced by texture (grain size/crystal) with a correlation coefficient of 68% (strong correlation). Meanwhile, the rock composition represented by the percentage of quartz shows a very weak relationship with a correlation coefficient of 18%.

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